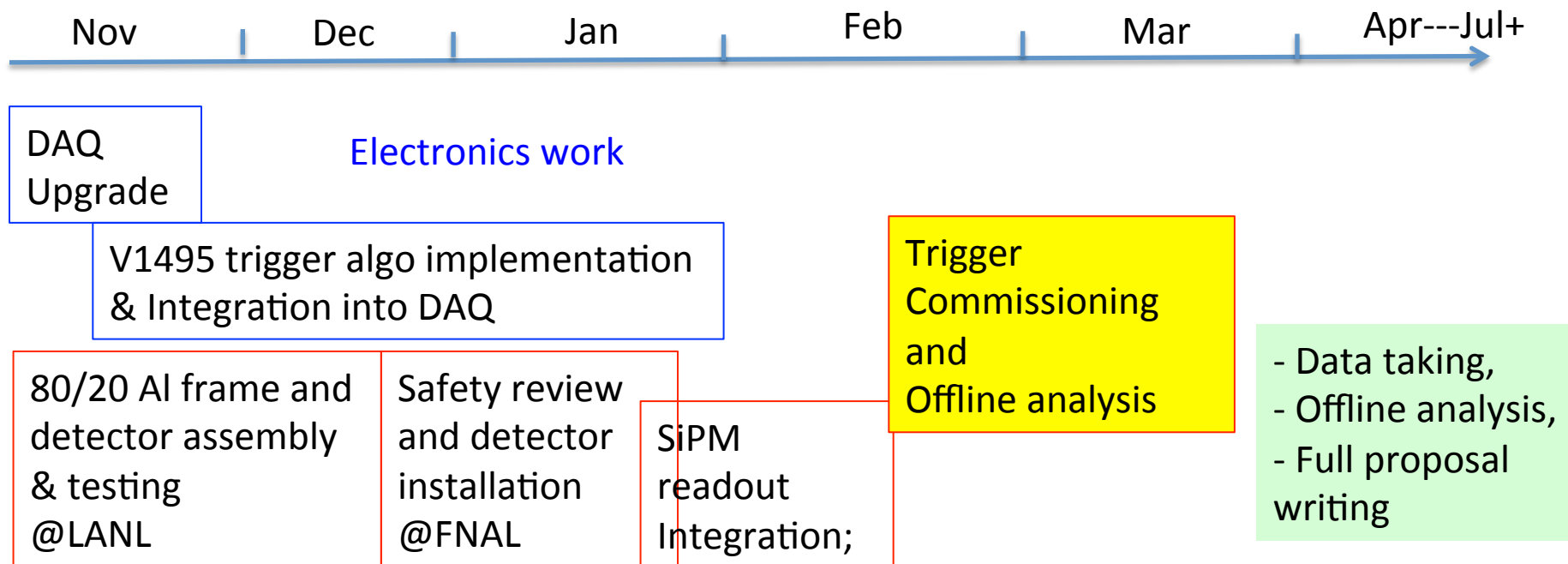


# FY17 Detector Effort



**Manpower needs: (estimated from experts, Kun, Hubert, Andi, Pat and Ming)**

- DAQ and V1495 work: 2 FTE\*Month
- Mechanical work: 1 FTE\*Month
- Commissioning: 1.5 FTE\*Month
- Add 25% contingency on labor
- Total Labor needs **~5.5 FTE \* Month** (in the project, ~10 FET\*Month in Exp effort)

Available people:

**Electronics work:** Kun, Andi, PostDoc/Sho, Student/Alex, Ming & Fermilab Engineer/collaborators (1 student + other postdocs)

**Mechanical work:** Hubert, Pat, Ming, Sho, Alex, Fermilab collaborators (1 student + other postdocs)

**Additional Engineer & Tech support (w/ \$\$) could help to reduce the schedule risk**

# FY-17 Work Plan Summary

## Goal: Complete DAQ and Trigger upgrade for a large fraction of E906 Run in FY17

- Installed and commissioned by the end of March 2017
- Parasitic data taking with E906 April – July, 2017
- Lead people: Kun, PD(Sho), Hubert, Andi, Pat, Ming and Fermilab collaboration (Engineer and students/postdocs)
- Trigger scintillator detector construction at LANL and Fermilab
  - Mechanical structure safety calculation and documentation (LANL student Kenie+Walt)
  - Fermilab safety review, started, on-going discussion, to be completed by the end of 12/2016
  - Ship 8 assembled frames to FNAL late December 2016
  - Installation of detectors by mid of January 2017
  - Lead people: Hubert, Ming, PD, Fermilab students/collaborators
- Readout electronics & LV/HV services
  - FNAL preamps production, received a quote, under \$23K, done by mid January 2017.
  - LeCroy 4413 from Fermilab, tested by mid Dec, 2017
  - Lemo cables (520) and 17-ch ribbon cables (35), tested by mid of January 2017
  - Trigger detector installation and commissioning by mid of Feb 2017)
  - Lead people: Ming, PD(Sho), Pat and collaboration (Fermilab and ANL)
- 
- V1495 trigger look-up table implementation
  - MC simulation, Collaboration (Univ. Of Michigan)
  - PD (Sho), Kun, Andi
- Integration and commissioning trigger electronics system
  - Feb – March, 2017
  - PD(sho), Kun, Andi, Ming and collaboration
- Data taking and physics analysis
  - April – Sep, 2017
- Full proposal writing to Fermilab PAC for dedicated runs in 2017+
  - Full physics and detector simulation with optimized setup
  - Electron and hadron identification
  - Full mass range coverage with di-electron and di-muons
  - Expanded physics program, including Dark-Higgs, missing-Energy dark matter etc
- Manpower on the project:
  - Kun(20%), PD(50%), Hubert(10%), Ming(10%)
  - Help from Andi(20%), Pat (10%), Alex (30%) and other PDs from the team during the construction
  - Fermilab student(50%) and Fermilab collaborators(Engineer, Tech and postdoc/student)

# FY-17+ Plan (Cont.)

- Whenever available, parasitic data taking with polarized Drell-Yan (E-1039) experiment in FY18 – FY19 as originally proposed.
- Carry out the first physics analysis using 2017 data and publish preliminary results
- Develop, submit and defend a full Dark Photon and Dark Higgs Search proposal to Fermilab PAC for future dedicated runs with upgraded detector for many years to come
  - Include adding Electro Magnetic Calorimeter (EMCal) to measure low mass dark photons below dimuon mass threshold (200MeV, current lower mass limit on dark photon search)
  - Dedicated long runs with much higher integrated luminosity beyond 2017
  - Obtained two “free” EMCal sectors from PHENIX experiment at RHIC
  - Future effort much depending on the outcome from first year’s preliminary results
- Received strong support from Fermilab PAC, Director and the Dark Sector Physics community on such proposal

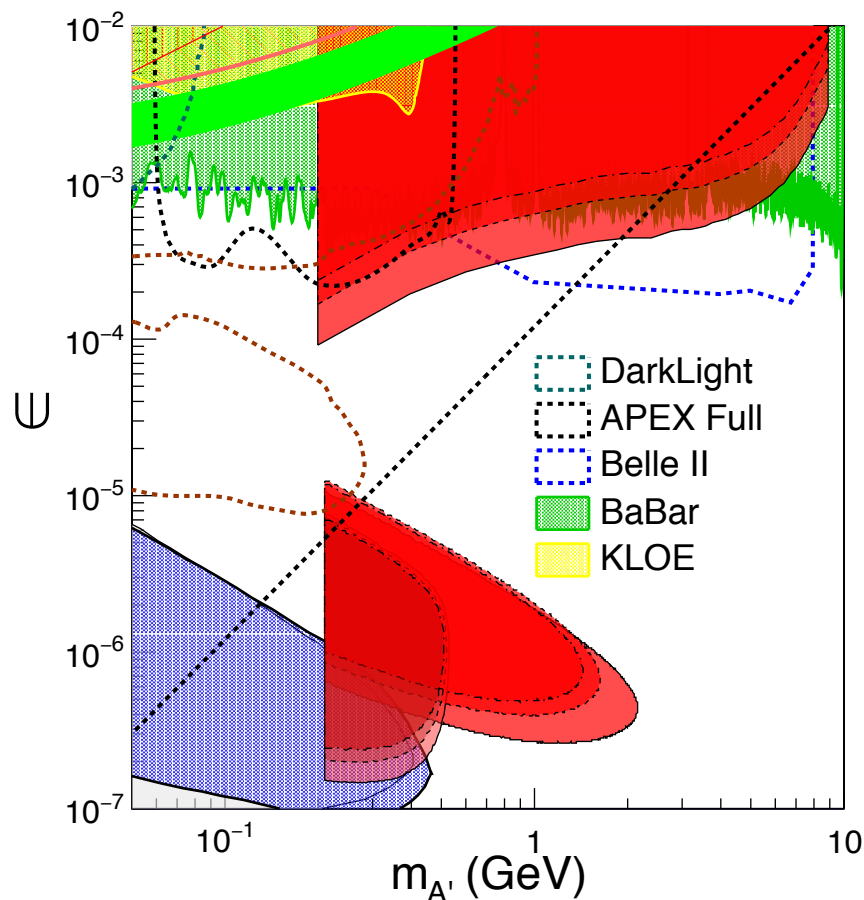
## Note on Fermilab future beam schedule:

- E1039 was originally planned to start data taking in ~May 2017, for two years.
- Recent changes of Fermilab’s run plan due to limited budget requires us to bring in additional external fund to install the polarized target and run the experiment.
- There is an on-going discussion between DOE–Fermilab to run E-1039 after summer 2017. A decisions will be made by DOE in January 2017.

Regardless of the outcome of DOE’s decision on the polarized Drell-Yan running at Fermilab, we plan to write a full proposal to have a dedicated dark photon and dark Higgs program beyond 2017 using Fermilab High Intensity Frontier Facility, also seeking additional fund from DOE NP and HEP

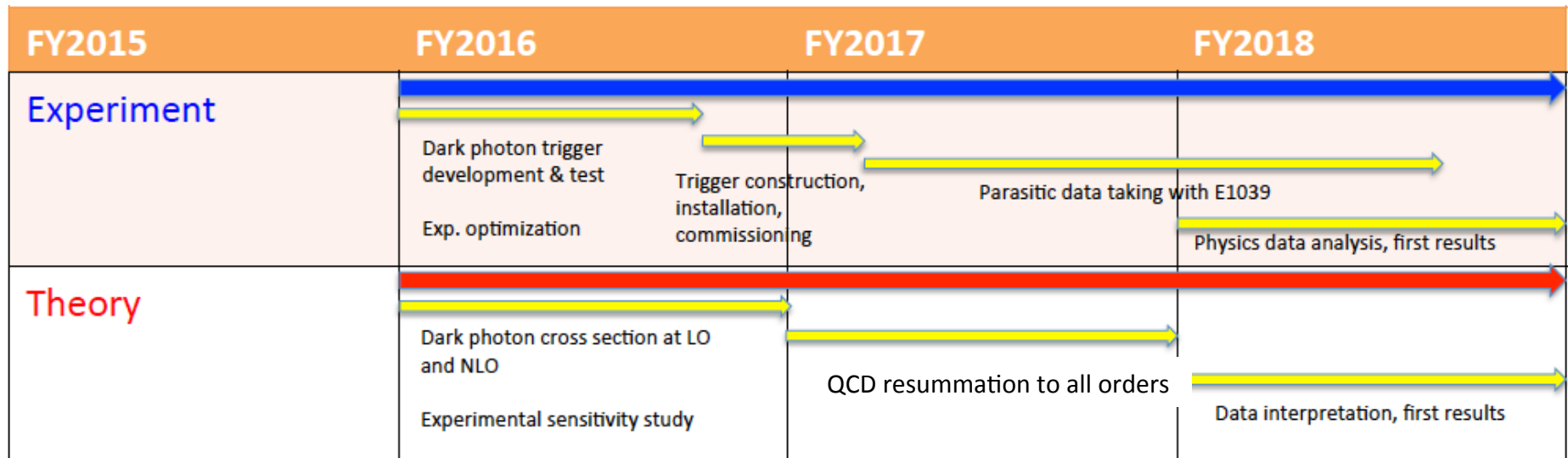
# Projected Sensitivities from 2017 E906 Trial Run: 2-mo, 4-mo and full 2-year parasitic run

- April – July 2017, assuming 4-month of parasitic running (middle dashed-line)
  - Also included projections for 2-month (dot-dashed-line) and 2-year long run (solid-line)
  - Even for 2-month run, we can still have significant measurements
- For prompt-DY-like dark photon search, the lowest  $\epsilon$  reach is proportional to  $1/\sqrt{\text{Lumi}}$  (Lumi, the integrated luminosity)
- For displaced dark photon search, the case is more complicated:
  - The upper limit is primarily limited by the decay length (kinematics) as most data statistics will be in this region, and not very sensitive to the change of statistics
  - The lower bound is primarily limited by the cross section/statistics and thus is proportional to  $1/\sqrt{\text{Lumi}}$



# LDRD Tasks & Schedules

**FY16: Accomplished all milestones and more!**



Today, good work in progress

# Back up slides

# FY-17 DAQ & Trigger Boards V1495

## Integration and Commissioning

- DAQ upgrade
  - By the end of November
- V1495 and DAQ integration
  - By Early Feb 2017
- Trigger commissioning
  - By mid March 2017
- Data taking
  - April – July 2017
- Lead persons:
  - Kun, PostDoc (Sho), Andi, Alex, Ming and help from E906 collaboration and other postdocs

# A New High-Granularity Displayed Dimuon Vertex Trigger

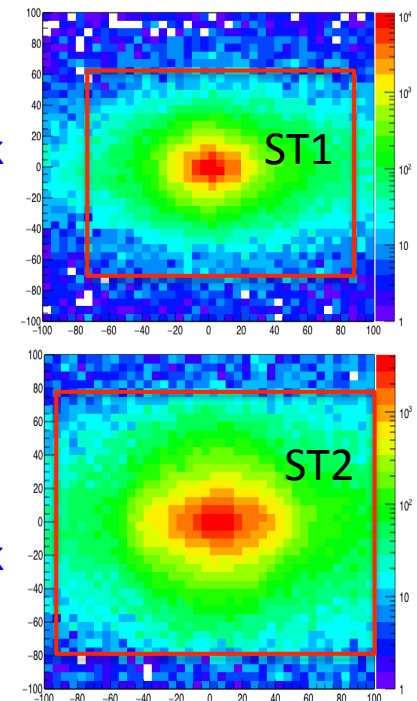
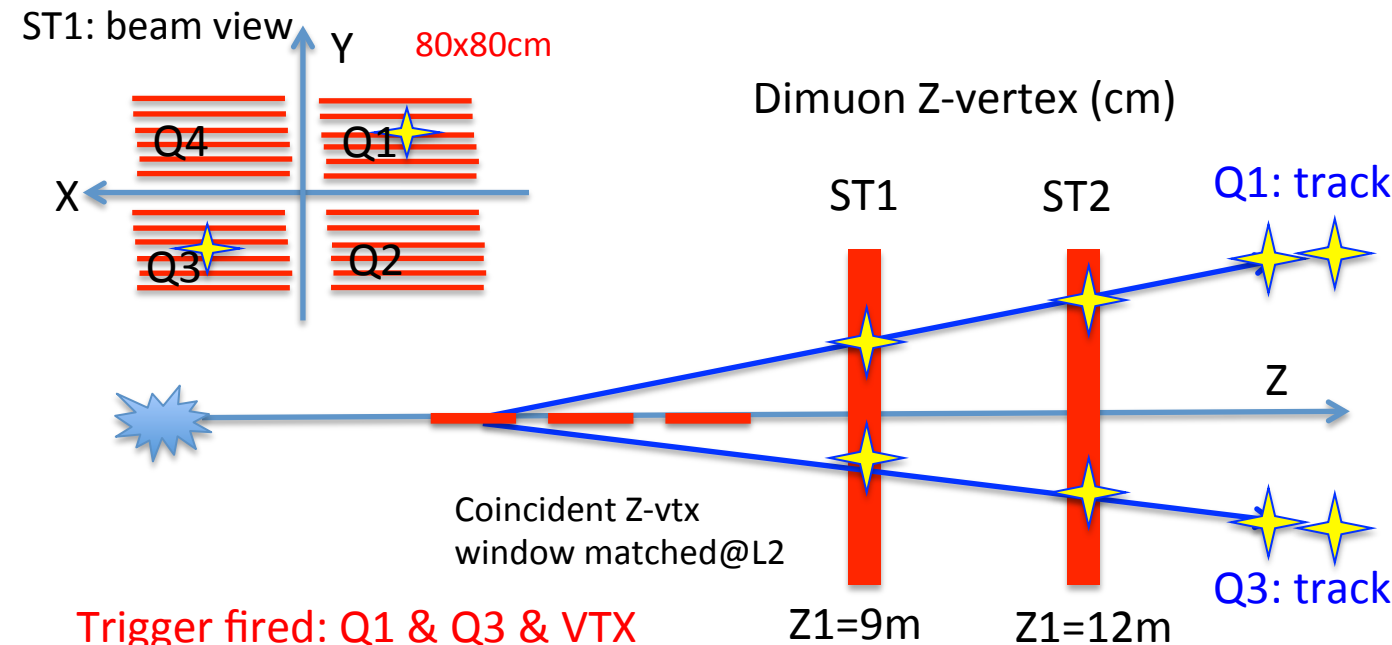
High rejection power, low rate,  $\ll 1$  kHz (current E906 DAQ limit)

## Y-Plane (non-bending) Trigger:

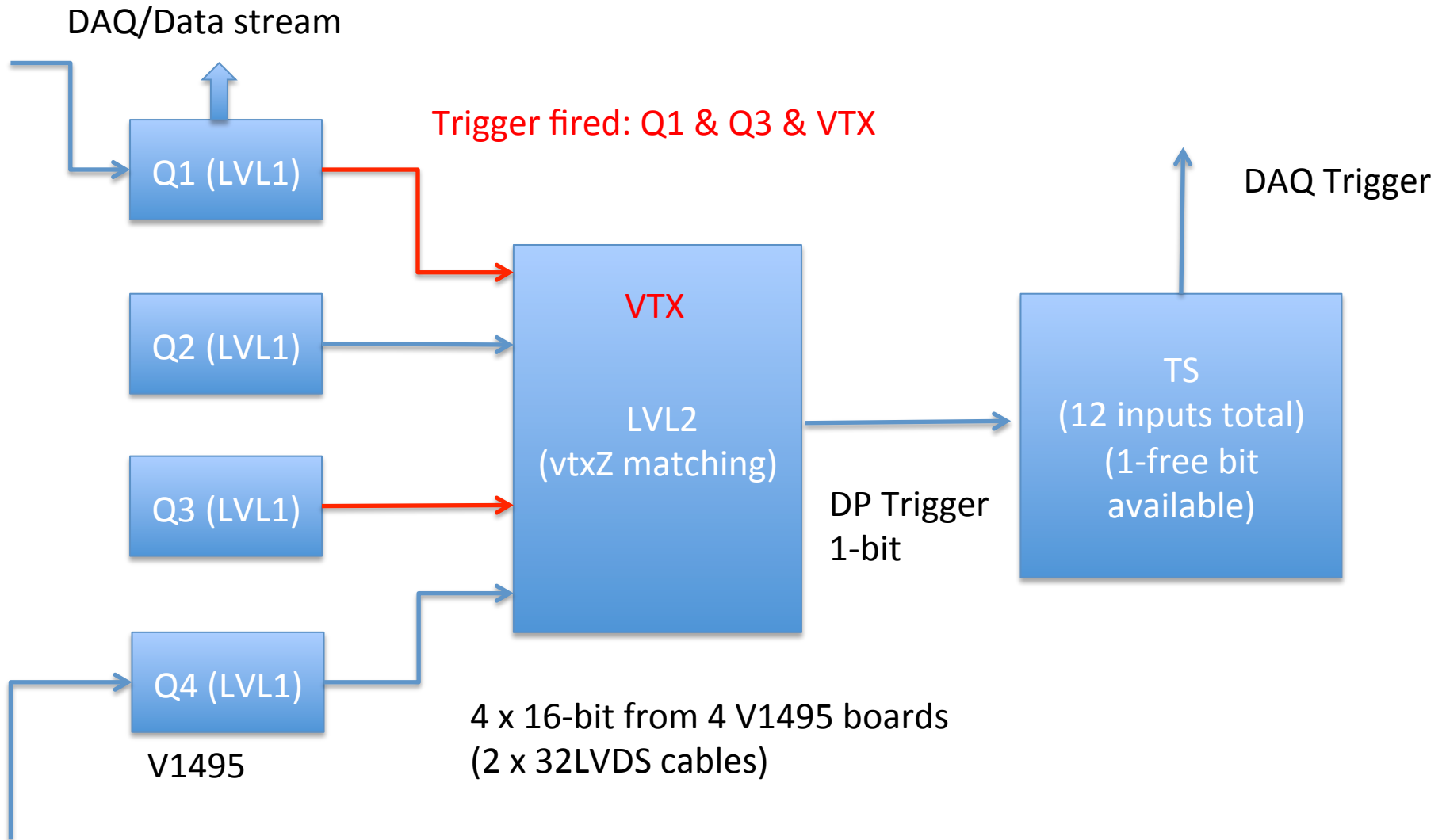
- A quadrant panel: 80cm x 80cm (100cmx100cm @ST-2)
  - ST1: 1cm x 1cm x 80 cm scintillating strips, SiPM readout
  - ST2: 2cm x 2 cm x 100 cm strips
- Straight line projection,  $\sigma_z \sim 30$ cm
- Displaced z-vertex, mostly low mass  $< 3$ GeV

## Y-channels per quadrant:

- 1x V1495
- $80(\text{St1}) + 50(\text{St2}) + 8 \times 2 (\text{St4-Y1,2}) = 146$
- $96 + 64 = 160$  inputs possible  
(2NIM=RFCLK+ComSTOP)



# Displaced Dark Photon Trigger Logic



Per quadrant  $Q_{(1-4)}$ :  $80(ST1) + 50(ST2) + 2 \times 8(ST4-Y1/2) = 146$ , FANOUT ST4 Hodo

# FY-17 Trigger Detector Construction & Installation

- Complete assembly and installed by end of January 2017
- All major hardware in hand
  - Scintillators (at Fermilab)
  - WLSF (at LANL)
  - All 80/20 Al frames at LANL
    - 4 frames completed, 4 more (identical) to go
- Frames assembled at LANL, ship to Fermilab for final assembly in December-January 2016
- Fermilab mechanical structure safety review before installation
  - Student/Kenie initial design, Walt to confirm
  - Hubert, Ming working with Fermilab Safety office
  - On-going progress as part of E906 startup, to be reviewed and approved for final installation by the end of Dec 2016
- Lead persons:
  - Hubert, Ming, Alex, PD and help from Fermilab Collaboration

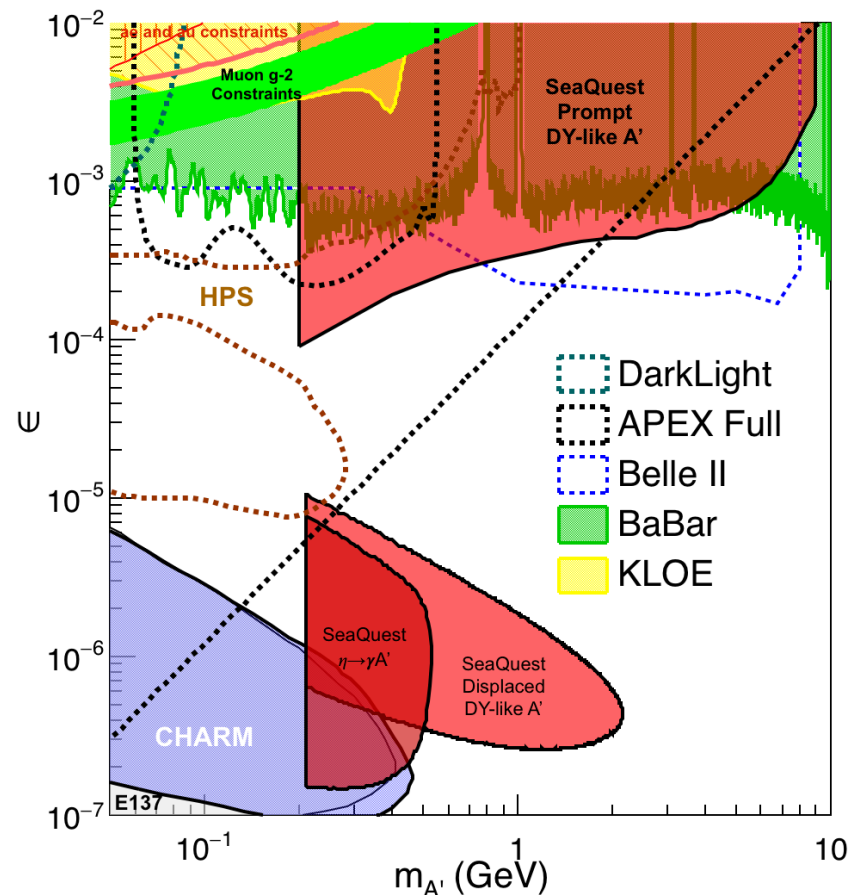
# SiPM readout and Services

- Fermilab premap cards production
  - Obtained a quote, cost: ~\$30/each, 700 total, under \$25K, good for credit card order
  - Done by early January 2017
- Discriminator and LV/HV PS
  - LeCroy 4413 and NIM crates available from Fermilab pool
  - Tested by the end of December
  - Reuse Fermilab HV PS and the 48-ch distribution cards (50~60V, I < 500 x 10uA )
- Cables
  - Recycle from previous Fermilab experiments
    - Lemo cables, 550
    - 34-ch ribbon cables
    - By mid of January 2017
- V1495 and VME crate and Controller CPU
  - In hand, need to update firmware based on E906 trigger code
  - Integration starts early December, complete by mid Feb 2017
- New Production of Taiwan TDCs
  - Being produced in Taiwan, for future upgrade of SeaQuest
  - Needs 8 for trigger upgrade, 15 delivered to Fermilab already
- Lead persons:
  - Ming, PD/Sho, Kun, Pat and Fermilab Engineer/Collaborators

# Projected Sensitivity with 2-year Parasitic Run with Polarized Drell-Yan E-1039 Experiment

- Parasitic run with polarized Drell-Yan
  - 2018-2019

Assuming 2-yr (400 days)  
of parasitic running

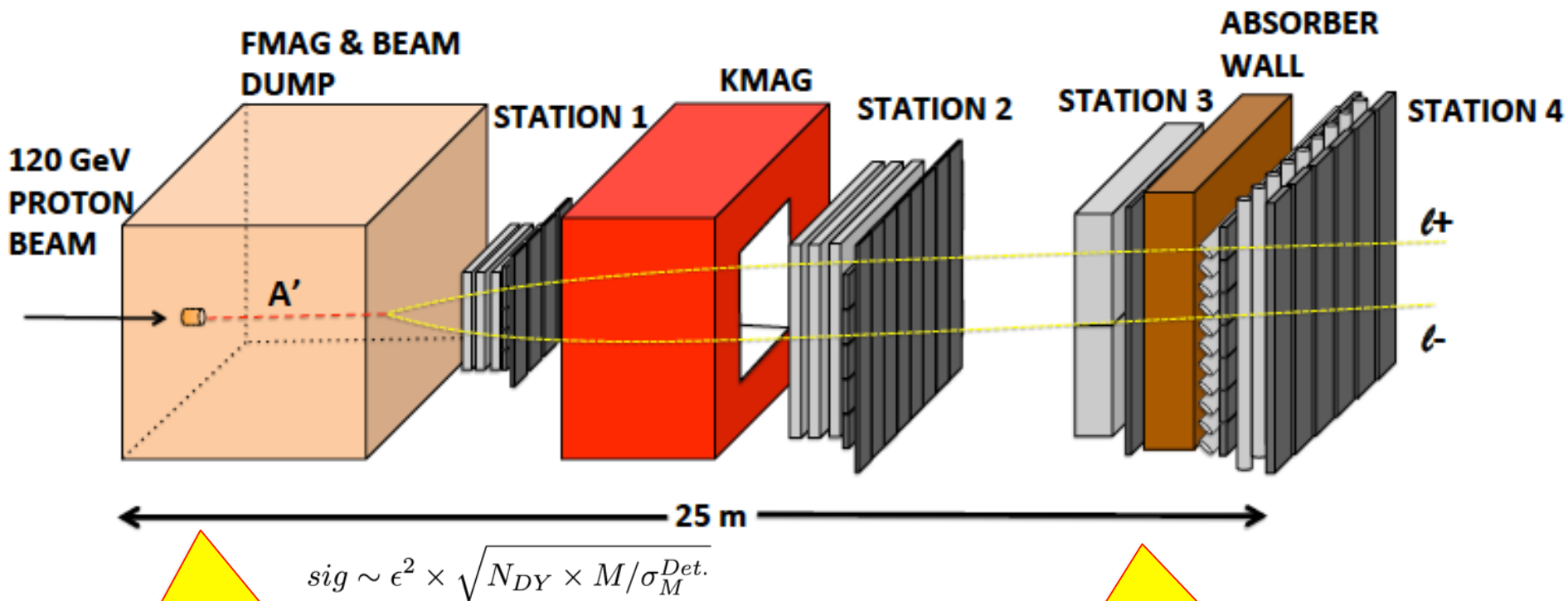


# If additional fund available in FY17...

- Given the uncertainty of future run beyond 2017 at Fermilab, it would be very helpful to have additional \$\$ and technical resource support to speed up the DAQ/trigger upgrade to take maximal amount of data out of current 2017 E906 run
- More manpower could be used to speed up assembly, trigger algorithm development, testing readout and installation, in particular in the following tasks:
  - Trigger logic FPGA programming support
  - Electronic tech to help SiPM readout and LV/HV installation and debugging
  - Mechanical engineer to prepare the Fermilab safety document
- Procurements of small items
  - Fiber-SiPM adaptors
  - Lemo and ribbon cables
  - Big frame to hold 4-frames per plane, detector pre-installation safety review
- Move PHENIX two EM Calorimeter sectors from BNL to Fermilab, installed at SeaQuest after the end of E906 run in summer 2017.
  - Free from PHENIX, a ~\$2M detectors, with PMTs and HV PS
  - Shipping cost ~\$10K

# E-1067 Future Upgrade: New Idea

2018 ~ 2025+



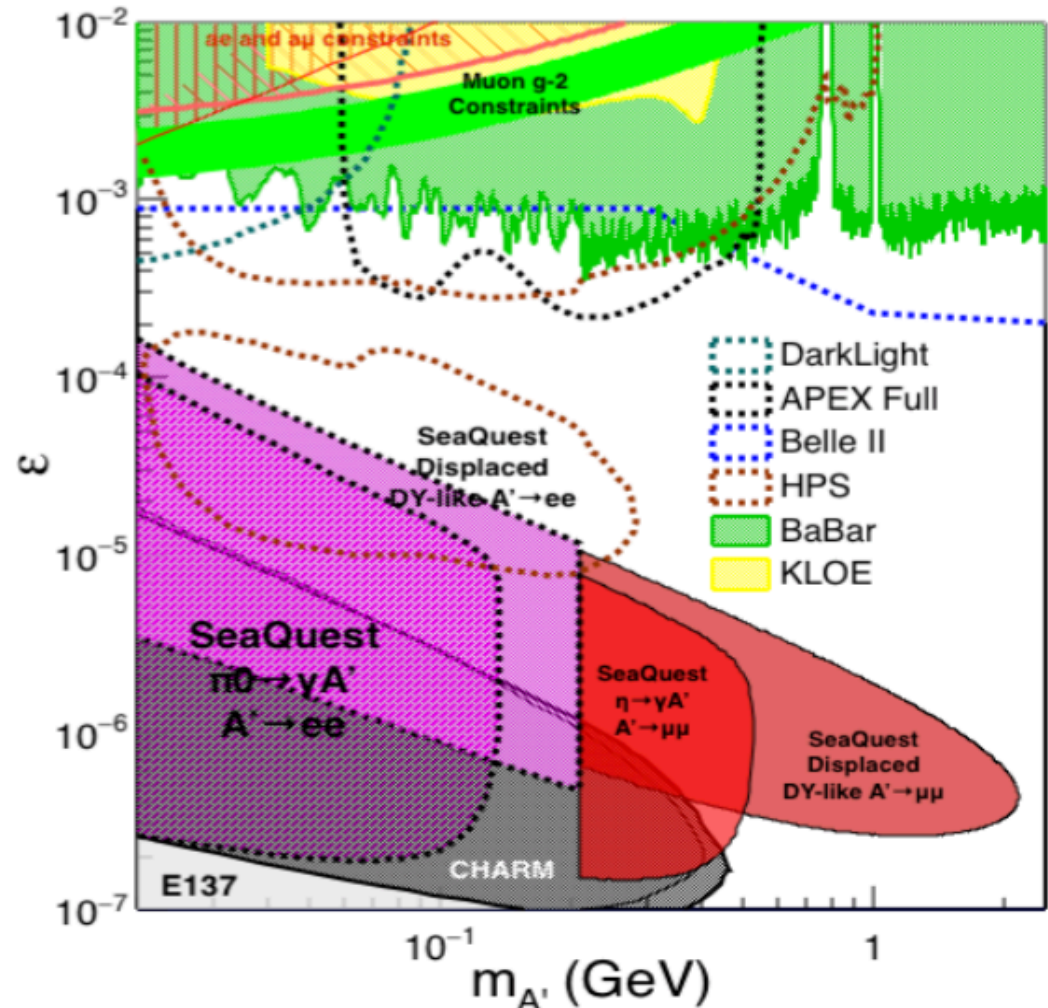
Add tracking detectors  
close to "target" to  
improve mass resolution

Add EMCal (recycled from  
PHENIX at RHIC) to identify  
 $e^{+/-}$ ,  $h^{+/-}$ ,  $\pi^{+/-}$

# Displaced Low Mass Dark Photons with EMCal upgrades

Projection: POT  $1.4 \times 10^{18}$

- Detector upgrades
  - EMCal:  $e^{\pm}$
  - HCal:  $\pi^{\pm}$
  - Recycle from other experiments, PHENIX/RHIC etc
- DAQ upgrade
  - 100+ kHz
- Timeline of runs
  - 2018+
- Detector configuration
  - Access low mass region with optimized Fmag setting

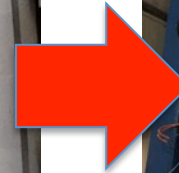
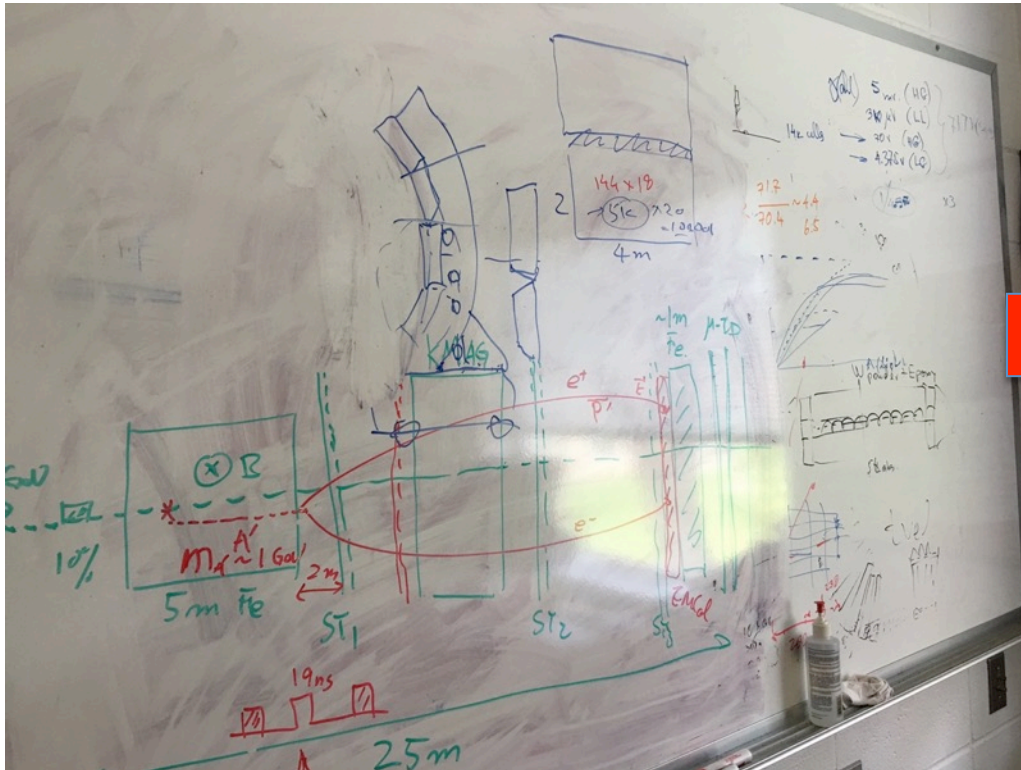


# EMCal Identified from PHENIX/RHIC

- 2 EMCal sectors are available from PHENIX experiment at RHIC, ~end of 2016
  - one EMCal sector is made of:
    - 2m x 4m, 18 (3x6) super modules
    - Super module = 36 modules; Module = 4 towers
    - $36 \times 4 \times 18 = 2592$  channels
    - Could gang 2x2 (or 3x3) into one ADC/TDC readout

Available in summer 2017 for installation at Fermilab

- $dE/E = 8.1\%/\sqrt{E} + 2.1\%$
- $dT < 200$  ps
- *Excellent  $e/\pi$  separation*



# Projected Dark Higgs Sensitivity

POT:  $1.4 \times 10^{18}$  (Phase-I)

Y. Zhang (2015)

- Dimuons with downstream displaced decay vertices
- Limited sensitivity to “prompt” large mixing case due to small cross-section
- Dark Higgs or dark photons?
  - Dimuon kinematic and angular distributions
- Phase-II
  - Dedicated high luminosity runs optimized for low mass acceptance,  $\text{mass} < 3 \text{ GeV}$

